

ROLE OF INFECTION, SUFFOCATION, AND BOTTLE-FEEDING IN COT DEATH

AN ANALYSIS OF SOME FACTORS IN THE HISTORIES OF 110 CASES AND THEIR CONTROLS

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Infant mortality rates for England and Wales continue to decline. However, this does not hold good for sudden deaths reported to coroners, and the cause of a large proportion of these cases remains obscure (Banks, 1958).

Three hypotheses have been offered in explanation by Barrett (1954): (i) an overwhelming infection, possibly of virus origin; (ii) suffocation from soft bedding; (iii) an anaphylactic type of reaction resulting from inhalation of cow's milk by a milk-sensitized child.

These hypotheses have been discussed with inconclusive results (Banks, 1958; Parish, Barrett, Coombs, Gunther, and Camps, 1960; Parish, Richards, France, and Coombs, 1964).

The purpose of this paper is to present the results of an analysis of some sociological data in the light of the three hypotheses.

MATERIAL

In twelve London boroughs and in the Administrative County of Cambridge, deaths reported to the coroners in children aged 2 weeks to 2 years were investigated as described by Banks (1958). Between September, 1958, and May, 1961, 170 deaths were investigated, sociological inquiry forms being completed by coroner's officers and health visitors.

In addition, in each case, comparable questionnaires were completed by health visitors for two live control children as soon as possible after the corresponding death had occurred. The method of selecting control children was to take the two nearest names on either side of that of the dead child in the Medical Officer of Health's register,

matching for sex and accepting only those children who were still living in the district. Thus the control children were matched for age, sex, and area of residence, and their clinical histories were matched for time of year. Controls were not selected for cases which had been resident for less than one month at the address at which they were taken ill or died and this, coupled with a few refusals, made only 301 controls available, representing 89 per cent. of the intended sample.

CLASSIFICATION OF THE CASES

Some of the deaths resulted from recognizable causes, *e.g.* congenital malformations of the heart. Such deaths, although sudden, are not the object of this investigation, which is primarily concerned with those cases in which the information available does not reveal or strongly suggest the true cause or causes of death. It is convenient to use the term "cot death" to describe such cases.

Pathological and bacteriological investigations have been carried out on some of these cases, but for others they are not complete. For the purpose of this study a provisional pathological classification was made by Dr R. W. Ainsworth on the data available. In 80 per cent. of the cases this classification was based on the clinical history and macroscopic *post mortem* findings (Table I*).

* Subsequent histological examination of lung sections of 33 cases provisionally classified as "cot death" revealed a cause of death in only two (6 per cent.) of them. In six out of thirteen cases which were provisionally classified as probably due to pneumonia, tracheo-bronchitis, etc., the cause of death could not be demonstrated histologically on the material available. Hence the provisional classification shown in Table I almost certainly underestimates the proportion of "cot deaths".

TABLE I
CERTIFIED CAUSE OF DEATH AND THE PROVISIONAL CLASSIFICATION OF 170 CASES OF SUDDEN DEATH IN INFANCY

Certified Cause of Death						Respiratory*				Non-Respiratory				Total
Time in Hospital before Death (hrs)						Nil	<12	12+	Total	Nil	<12	12+	Total	
Provisional Classification	Cot Deaths					107	2	—	109	1	—	—	1	110
	Other Deaths	Respiratory				21	6	3	30	—	—	—	—	30
		Non-respiratory				2	—	—	2	21	2	5	28	30
Total						130	8	3	141	22	2	5	29	170

* The following causes were regarded as respiratory:

Cause	International Classification of Disease No.
(a) Upper respiratory infections, influenza, pneumonia, bronchitis, and other diseases of the respiratory system	470-475, 480-483, 490-493, 500-502, 510-527
(b) Pneumonia of newborn	763 and 763.5
(c) Accidental mechanical suffocation	E921-E925

Table I shows the causes of death certified by the coroners divided into respiratory and non-respiratory causes, and the length of time the child was in hospital before it died. It also shows which of the deaths were provisionally classified as "cot deaths", and which could be attributed to some definite respiratory or non-respiratory cause. All but one of the 110 cot deaths were certified as due to respiratory causes, and 77 per cent. (109) of the 141 deaths certified as due to respiratory causes were provisionally classified as cot deaths.

Cot deaths are likely to be certified differently in different areas, but it seems clear that in most instances the circumstances of death and the *post mortem* findings are such that they are certified under one or other of the respiratory causes of death shown at the foot of Table I.

NATIONAL STATISTICS

There are no published national statistics of the numbers of cot deaths. However, the General Register Office has kindly prepared special tabulations relating to the number of deaths among children aged between 2 weeks and 2 years in England and Wales in 1955, 1958, and 1960. The basic data are given in Table II, which shows that, despite a 5 per cent. rise in the number of births between 1955

TABLE II

TOTAL NUMBER OF DEATHS, RESPIRATORY DEATHS, AND RESPIRATORY DEATHS CERTIFIED BY CORONERS IN INFANTS AGED FROM 2 WEEKS TO 2 YEARS, BY SEX ENGLAND AND WALES, 1955, 1958, and 1960

Sex	Male			Female		
	1955	1958	1960	1955	1958	1960
Year						
Total Deaths	3,952	3,716	3,784	3,041	2,856	2,997
Total Respiratory	1,725	1,608	1,681	1,197	1,216	1,254
Deaths						
Respiratory Deaths	851	902	960	581	635	714
Certified by Coroner						

and 1960, the total number of deaths in the age group fell from 6,993 in 1955 to 6,572 in 1958 and rose by only 3 per cent. to 6,781 in 1960. During the same period the number of respiratory deaths certified by the coroners, of which on the evidence of Table I about four-fifths will have been cot deaths, rose steadily from 1,432 to 1,674. Thus, although the total death rate and total respiratory death rate fell significantly for both sexes between 1955 and 1958 and continued to fall, although not significantly, between 1958 and 1960, rates of respiratory deaths certified by the coroners showed no significant variation. Many factors may affect these figures, but as they stand they suggest that cot deaths are not decreasing in frequency as are other forms of infant mortality.

In 1960, 1,322 of the 1,674 respiratory deaths certified by the coroners occurred in the home. If the ratio of cot deaths to coroners' respiratory deaths (excluding hospital deaths) observed in the survey is applied to this figure, it produces an estimate of about 1,090 cot deaths in England and Wales in 1960.

TABLE III
COT DEATHS BY AGE AND SEX

Age (mths)	Sex		Total
	Male	Female	
Less than 1	1	5	6
1—	5	12	17
2—	17	12	29
3—	16	7	23
4—	4	7	11
5—	2	1	3
6—	4	6	10
9—	3	2	5
12—	1	3	4
18—23	1	1	2
Total	54	56	110
Average Age (mths)	4.3	4.4	
Standard Error of Average	±0.53	±0.54	

TABLE IV
MONTH OF COT DEATHS

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of Cot Deaths ..	13	16	18	10	12	5	2	5	2	9	8	10	110

Note: The period of this survey was September 1, 1958 to June 30, 1961

SOCIOLOGICAL SURVEY

Age.—Table III shows the age-sex distribution of the 110 cases classified as cot deaths and indicates that the greatest numbers occur in the 2- to 3-month age groups. The peak appears to occur at a slightly earlier age for females than for males, but the difference in the two age distributions is not statistically significant.

Sex.—There were more female than male cot deaths in the survey, but the age-sex distribution of these does not differ significantly from that of all coroners' respiratory deaths.

Time of Year.—Table IV shows the calendar month in which the 110 deaths occurred. The survey does not cover quite three years, so that 9.7 deaths are expected each month, except for July and August, when only 6.5 deaths per month are to be expected. An excess of deaths occurred during the winter months, which is statistically significant ($0.05 > P > 0.01$). This finding is in agreement with other surveys of sudden death in infancy (Banks, 1958; Jacobsen and Voigt, 1956).

There is a seasonal variation in the percentage of births per month. In England and Wales, this variation is less than ± 10 per cent. The percentages are above average between March and July, and below average from August to February, except for January, when they are usually close to average. The proportion of births is lowest in November. Since 68 per cent. of the cot deaths occur between the ages of 2 weeks and 4 months, the seasonal variation of

births does not explain the excess of cot deaths in January, February, and March.

Symptoms of Illness in the Last Two Weeks.—Table V and Fig. 1 show the numbers and percentages of cases and controls who had symptoms of illness in the last two weeks before death. The information regarding symptoms of 100 of the control children relates to the last two weeks of the dead child's life. For the remaining 66 controls for whom definite information is available, the replies relate to the last two weeks before the form was completed, which was generally a week or two later.

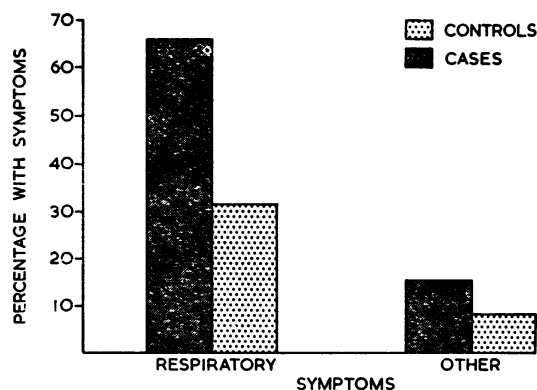


FIG. 1.—Percentage of cases and controls who had respiratory or other symptoms of illness in the last two weeks before death.

Included under symptoms of respiratory infection were:

Colds, otitis media, ear discharge, influenza, snuffles, catarrh, sore throat, whooping cough, bronchitis, pneumonia, and measles. Diarrhoea was taken as a symptom of an intestinal infection and gastro-enteritis had sometimes been diagnosed by a medical practitioner in the last fortnight.

Included as other symptoms were:

Pale colour, constipation, off feed, colic, anaemia, thrush, vomiting, pains, sores, discharging eyes, and eczema.

Napkin rashes, poor development, prematurity and physical or mental defects were not included under the headings of Table V but were coded separately. Two of these cases were mentally defective, one being a mongol, and one had a cardiovascular defect.

TABLE V
SYMPTOMS OF ILLNESS IN LAST TWO WEEKS BEFORE DEATH

Symptoms	Cases		Controls	
	No.	Per cent.	No.	Per cent.
None	20	20.6	102	61.5
Symptoms of Respiratory Infection	66	68.0	53	31.9
Symptoms of Gastric Infection only	2	2.1	—	—
Other Symptoms Only	9	9.3	11	6.6
Total	97	100	166	100
Not Known	13		30	
Grand Total	110		196	

It should be noted that only a definite reply "no illness" or a dash against the questions relating to symptoms was accepted as indicating that the child had no symptoms. It is probable that most of those shown as "not known" in fact had no symptoms.

Children with respiratory and gastric or other symptoms are shown as having respiratory symptoms.

Symptoms of respiratory infection occurred more than twice as frequently among the cases as among the controls. The difference is statistically highly significant ($0.001 > P$). The cases also included a higher percentage of babies with non-respiratory symptoms than the controls, but this difference is not statistically significant.

Although there is this marked difference between the percentage of cases and controls with respiratory symptoms, it could be argued that bereaved parents, seeking to find some explanation for the tragedy, are more likely than the mother of a living control to recall minor symptoms. There may have been a little bias of this kind, as 50 per cent. of the cases with respiratory symptoms had been seen by a doctor compared with 56 per cent. of the controls with respiratory symptoms. However, had there been a marked degree of over-reporting of minor symptoms among the cases, a much greater difference might have been expected.

Sleeping Conditions.—Of the 110 cases, 86 (78.2 per cent.) were discovered dead, nineteen (17.3 per cent.) were discovered ill, and five (4.5 per cent.) were taken ill while under observation. Among those discovered ill were several who may in fact have been already dead.

Since the death or the onset of the fatal symptoms in 95 per cent. of the cases occurred while the child was in its cot or pram, the nature of the bedding has been tabulated in Table VI. The bedding of the cases when last found was very similar to that normally used, but pillows were more often used, and both

pillows and mattresses are more often described as soft for the cases than for the controls. All three differences are statistically significant, the levels of significance being 0.001, 0.05, and 0.01 respectively.

The hardness of the pillow or mattress is a matter of opinion and differences in this respect could be due to the fact that a coroner's officer assessed the bedding of the cases and a health visitor that of the controls. However, the presence or absence of a pillow is a far more objective measure, and the difference between the normal sleeping conditions of the cases and controls is highly significant in this respect.

Fourteen of the cases were in bed with others at the time of discovery, although for only six was this normal. Only two of the controls normally slept with others. Many of the cot-death cases were taken into bed with their parents because they were restless. Twenty of the cases were found with mouth and nose completely covered by bedding.

It has been suggested (Brown, 1960) that, if cot-death results from a modified form of anaphylactic reaction after the inhalation of vomit, then it could be avoided if babies were put to sleep face downwards. However, cases included in this study were found face downwards rather more frequently than would be expected from their normal sleeping habits or from those of the controls, the differences being statistically significant (0.05 and $0.01 > P$ respectively). It seems, therefore, that sleeping face downwards is unlikely to prevent cot death. Agonal movement may, of course, affect the position in which the child is found. The percentage of cases and controls normally sleeping face downwards was very similar.

Breast-Feeding.—Histories of feeding from birth were provided for cases and controls from health visitors' records. These data are not necessarily

TABLE VI
SLEEPING CONDITIONS

Type of Bedding		Cases				Controls	
		When last Found		Normal Conditions		Normal Conditions	
		No.	Per cent.	No.	Per cent.	No.	Per cent.
Pillow	None	51	47.2	51	48.1	135	70.7
	Hard	18	16.7	19	17.9	33	17.3
	Soft	39	36.1	36	34.0	23	12.0
	Total	108	100	106	100	191	100
Mattress	None	1	0.9	1	0.9	1	0.5
	Hard	61	56.0	63	58.4	147	77.0
	Soft	47	43.1	44	40.7	43	22.5
	Total	109	100	108	100	191	100

a complete record up to the age at death because of the irregular contact between the health visitor and the child; there is, however, no apparent bias between cases and controls. Using all complete records, the numbers of cases and controls wholly and partly breast-fed at various ages have been tabulated and expressed as percentages of the available histories (Table VII and Fig. 2). Only 56 per cent. of the cases were wholly breast-fed for the first two weeks of life compared with 70 per cent. of the controls. Thereafter, the percentage breast-fed falls rapidly with age in both groups. By means of a modified form of life table analysis, it may be shown that the duration of complete breast-feeding is significantly shorter ($0.01 > P$) in cases than controls. This difference also holds for those cases and controls which were initially breast-fed.

Numerous cross-tabulations could be made, but it was decided to investigate thirteen factors in a discriminant analysis, restricted to cases and controls with sociological histories which included answers to all thirteen questions. There were 82 cases and 146 controls meeting this condition. These 146 controls were tested as regards age and sex to see if they could be regarded as a random sample of the theoretical number of 164 and this hypothesis was not discredited; in case there were any discrepancies, however, sex was added as a co-variance factor to the thirteen factors.

Comparisons of doubtful validity (*e.g.* how cases were last found compared with how controls were normally found, and histories of symptoms) were deliberately included in this analysis to see whether differences between cases and controls in the use of

TABLE VII
HISTORY OF BREAST-FEEDING AT VARIOUS AGES

Age	Cases						Controls					
	Available Histories	Breast-Fed				Available Histories	Breast-Fed					
		Wholly		Partially			Wholly		Partially			
		No.	Per cent.	No.	Per cent.		No.	Per cent.	No.	Per cent.		
Birth	103	58	56·3	18	17·5	186	131	70·4	25	13·4		
2 wks	103	40	38·8	18	17·5	186	108	58·1	22	11·8		
1 mth	97	24	24·7	15	15·5	177	74	41·8	13	7·3		
2 mths	80	7	8·8	8	10·0	151	40	26·5	11	7·3		
3 mths	54	3	5·6	2	3·7	97	21	21·6	3	3·1		

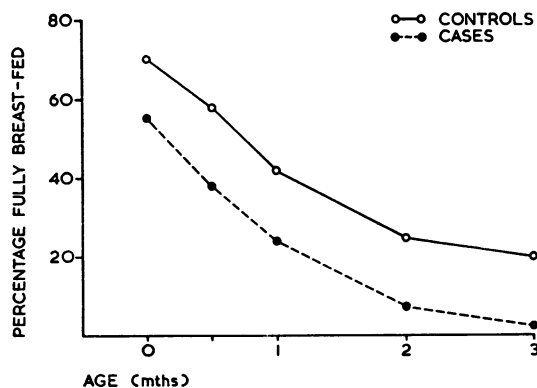


FIG. 2.—History of breast-feeding of cases and controls based on all available histories up to each age.

Combined Analysis.—From the preceding three sections it appears that, for these 110 cases and their controls, cot death is associated with a history of respiratory symptoms, the use of soft pillows and mattresses, getting the mouth and nose covered by bedding, and a history of early bottle-feeding. These various factors are interrelated.

pillows and bottle-feeding could be explained, however implausibly, in terms of these other factors. The analysis showed that they could not, and that the following factors were statistically significant:

Factors				Statistical Significance
Soft Pillow	..	..	..	0.01 > P
Shared Bed	..	..	..	0.05 > P
Bottle-feeding during First Two Weeks of Life	..	..	..	0.05 > P
Found with Bedding covering Mouth and Nose:				
Completely	..	..	..	0.001 > P
Partly	..	..	..	0.01 > P
History of Respiratory Symptoms	..	..	..	0.001 > P

The remaining factors (namely, a history of non-respiratory symptoms, the use of a pillow, the use of a soft mattress, sleeping face downwards, partial bottle-feeding in the first two weeks of life, and partial or complete bottle-feeding immediately before death) were not statistically significant.

Other Comparisons.—Cases and controls have been compared with regard to all questions included in the sociological questionnaire. They enabled a number of possible causes of the unexplained deaths to be excluded, *e.g.* using paraffin heaters; lack of adequate ventilation; viruses carried by birds, other pests, or vermin; vaccination or immunization.

Histories of eczema and asthma and hay fever were also compared in cases and their families with those in controls and their families. There was no evidence to suggest that cases or their families had an increased incidence of allergic conditions.

Analysis of the data also shows that cases of unexplained sudden death generally come from a poorer type of home than the controls, although living in the same area. This is brought out by the health visitors' opinion of the general standard of mothering and of the home, by the number of visits paid to the home, and the number of visits to the infant welfare clinic. It is also suggested by the facts that a higher percentage of cases were illegitimate (18 per cent. compared with 8 per cent.) and that their mothers were younger (14 per cent. being under 20 years of age compared with 2 per cent.). Also the social class of the chief wage-earner was lower and there were more persons per room in the homes of cases than of controls.

DISCUSSION

The sociological data collected have been examined for evidence regarding three hypotheses as to the cause of cot deaths: infection, suffocation, and hypersensitivity reaction.

The infective hypothesis is supported by the finding that the prevalence of respiratory symptoms in the last two weeks before death is a significant factor differentiating cases from controls. The difficulty of obtaining reliable data on symptoms is obvious, but the fact that relatively twice as many cases as controls had been seen by a doctor in connexion with respiratory symptoms strongly suggests that the association is real. But although respiratory symptoms were common among the cases there is nothing to suggest that they were generally all severe or that they heralded an overwhelming infection. Twenty cases had no symptoms of illness before death, and in seven of these cases there was no history of illness of any kind in the household.

The suffocation hypothesis is supported by the finding that the use of a soft pillow is a significant factor differentiating cases from controls. This difference may be explained by the fact that the hardness of the pillow was assessed by different people in different circumstances, but the fact that

cases were more often put to sleep with a pillow than controls cannot be so explained. In addition, these cot-death cases were last found with mouth and nose partly or completely covered by bedding, and in bed with others, significantly more frequently than was normal for the control children. But, as already stated, these last two comparisons are of doubtful validity.

Realizing how difficult it is to sum up the risk of suffocation, the coroners' officers were asked to express a confidential personal opinion as to whether there was *any risk at all* of the child having suffocated. Of 99 answers, in only 33 was the answer in the affirmative.

Jacobsen and Voigt (1958) similarly reported that the face was found covered in 32 per cent. of unexplained sudden and unexpected infant deaths. This is remarkably similar to findings reported in the last paragraph. Jacobsen and Voigt, however, dismiss these findings as an attempt to rationalize the event by the parents. They quote Woolley (1945), who demonstrated that a diminution in the oxygen tension of the inspired air is producible only when the infant's face is covered by a close-woven rubber fabric, not with an ordinary porous fabric. Barrett (1954) also thought suffocation unlikely to be the cause of cot death, but conceded that the histological changes seen in three cases in which death was almost certainly due to asphyxia were identical with those seen in cot death.

In favour of the hypersensitivity reaction to cow's milk hypothesis is the fact that in only four cases was the last feed before death reported to have been from the breast. There is also a marked difference between cases and controls in the duration of breast-feeding. Also in favour of hypersensitivity being in some way involved is the fact that the symptoms of hypersensitivity to cow's milk are vomiting, failure to thrive, gastro-enteritis, and chronic or recurrent respiratory infection (*Brit. med. J.*, 1963). These symptoms commonly occur in the clinical histories of these cases.

It must be admitted that the lower general standard of mothering among the cases would be expected to be associated with early bottle-feeding and the use of soft bedding, and the presence of more persons per room, a higher proportion of shared beds, and more children in the household, with an increased incidence of infections. However, a poorer type of home, more sibs, prematurity, and poorer general development do not in themselves provide a cause of death.

The data do, however, provide some evidence in favour of each of the three hypotheses as to the cause of cot death. It is likely that cot deaths may arise from a variety of causes, and that no single hypothesis

can fully explain them all. A possible explanation of our findings, however, may be that cot deaths result from a long chain of events. For instance, respiratory infection might cause a blocked nose. Then, if for some reason the child's mouth became obstructed, it would begin to suffocate, which in turn might cause it to vomit. Finally, aspiration of vomit containing cow's milk might set off a fatal anaphylactic reaction if the child were hypersensitive to it.

SUMMARY

- (1) Tabulations provided by the General Register Office, and sociological data relating to 110 "cot deaths" and 196 matched controls are analysed.
- (2) It is suggested that there were probably about 1,100 "cot deaths" in England and Wales in 1960.
- (3) The sociological data show that "cot death" is significantly associated with the use of a soft pillow, bottle-feeding, especially during the first two weeks of life, and symptoms of respiratory disease in the two weeks before death.
- (4) Cases and controls are also compared with regard to several other factors.
- (5) Three hypotheses as to the causes of "cot death" are discussed.

We are most grateful to the General Register Office for special tabulations summarized here, and for permission to use them.

We are also very greatly indebted to the coroners' officers and health visitors, who carried out the inquiries

on which this survey is based, often in trying circumstances. On their behalf we wish to thank H.M. Coroners Mr V. O. D. Cade, Dr A. G. Davies, Mr D. V. Durrell, and Dr R. I. Milne, and also the Medical Officers of Health, Dr J. A. Scott and Dr P. A. Tyser.

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Finally, we are indebted to the Cambridge Mathematical Laboratory for permission to use their electronic computer EDSAC for this analysis.

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